On-Chip Quantum Repeater in Diamond for Space-Based Quantum Communication

Completed Technology Project (2012 - 2017)

Project Introduction

The focus of my research is on the optical properties of diamond. A diamond is composed of a crystal arrangement of carbon atoms and it is this structure that gives it strong mechanical forces along a single crystal direction. Due to this structure, diamonds mechanical properties have been the center of much research in materials science and mechanical engineering for much of the past century. However, in the past two decades, optical scientists have also discovered another use for the diamond. Due to the same mechanical property explained above, when a nitrogen substitution defect is in diamond, it also remains very stable. It is this stable, nitrogen impurity in diamond that will be the center of my investigations. Atomic physicists have been pioneering the work in manipulating atoms for applications in quantum communication. Quantum communication comprises of three major components: transportation (via photons), storage (via nuclear spins or atoms), and processing (via microwaves) of information. Though many of the major processes for this vision have been experimentally realized in the last two decades on individual atoms, much more work remains to be done to culminate in a quantum communication protocol. The optical state of the nitrogen atom, such as its energy levels, can be accessed and read out by illumination and detection of photons. The single nitrogen impurity atom is essentially well trapped by the crystal lattice of carbons, and allows for convenient investigation without the need for building a complex apparatus for trapping a single atom. The first stage of my research will be to controllably write to and read out of highly stable nitrogen impurities in diamond to act as a quantum memory node or also a highly sensitive magnetometer. The memory node being the state of the atom, and the sensitive magnetometer being from how environmental conditions, such as an applied magnetic or electric field, affect the read-out of the nitrogen impurity. One specific application to which I will be working towards is an in-situ method of measuring the electric pulses of neurons in mice using nanometer-sized diamonds. These nanodiamonds would potentially be useful for the live-imaging of neural activity of biological systems in space. The guiding and manipulating of light on a compact chip is known as integrated optics. In the second stage of my research, I aim to engineer structures onto diamond solids or other materials such that light can be guided into and out of the nitrogen impurity for optical manipulation in a compact and scalable manner. This would fully implement the diamond impurity as a quantum repeater to enable quantum communication over even further distances. Quantum communication through space has also recently been laid in two ways. The first step was taken by scientists at NASAs Goddard Space Flight Research Center. In the past decade, they began implementing optical, rather than microwave communication hardware which has enabled about 100 times faster data communication rates between much of the space based instruments under NASAs direction. This upgrade has been popularly likened to NASAs internet going from a dial-up modem to todays high-speed fiber optic based internet speeds. The second step has been taken by physicists

Project Image On-chip Quantum Repeater in Diamond for Space-based Quantum Communication

Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

On-Chip Quantum Repeater in Diamond for Space-Based Quantum Communication

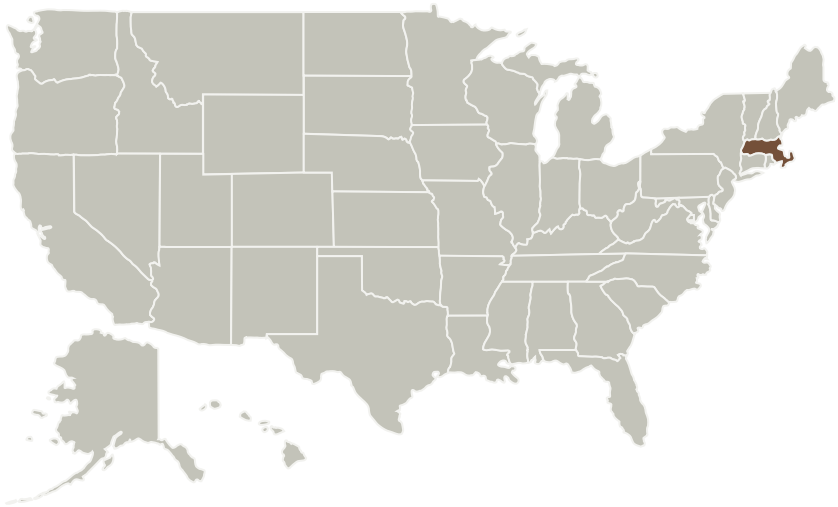
Completed Technology Project (2012 - 2017)

that have demonstrated entanglement over a distance of 144km through space. As communication moves to, and will probably remain, in the optical regime, quantum communication will grow more and more relevant to NASAs communication technologies. I have thus listed two major applications for diamond in this proposal: neurobiology and quantum communication. Without a doubt, both fields will play an important role in the next stage of NASAs endeavor for space exploration.

Anticipated Benefits

There are two major applications for diamond in this proposal: neurobiology and quantum communication

Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations
Massachusetts

Project Management

Program Director:
Claudia M Meyer

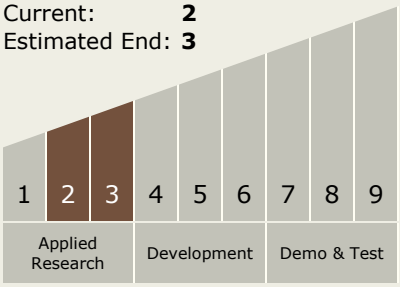
Program Manager:
Hung D Nguyen

Principal Investigator:
Dirk Englund

Co-Investigator:
Edward Chen

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  - TX05.5 Revolutionary Communications Technologies
    - TX05.5.2 Quantum Communications

On-Chip Quantum Repeater in Diamond for Space-Based Quantum Communication

Completed Technology Project (2012 - 2017)

Images

11484-1363262245230.jpg
Project Image On-chip Quantum Repeater in Diamond for Space-based Quantum Communication
(https://techport.nasa.gov/image/1808)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html